Low-Level Conduits – Rehab or Replace?

Introduction

Deterioration of low-level outlet conduits is a common problem, especially for older embankment dams. This article presents alternatives designers should consider prior to beginning a conduit replacement or rehabilitation project and a brief discussion of the potential pitfalls sometimes seen during the design and construction phases.

Rehabilitation or Replacement?

The first question the designer needs to ask is whether the conduit should be replaced or is a good candidate for rehabilitation. Conduit replacement is likely the approach providing the greatest reliability, but that approach will most likely require draining of the reservoir and be the highest cost option. In some cases, rehabilitation provides a reasonable alternative. Rehabilitation is typically accomplished by one of two methods, sliplining or cured-in-place pipe (CIPP) liners. Sliplining is completed by installing a smaller, "carrier pipe" into a larger "host pipe", grouting the annular space between the two pipes, and sealing the ends. A CIPP liner is a resin-saturated felt tube made of polyester, which produces a jointless, seamless, pipe-within-a-pipe. A CIPP liner is either inverted or pulled into the host pipe, cured-in-place using pressurized steam or hot water and serves as the new carrier pipe. Although these rehabilitation methods may also require draining of the reservoir, they are typically lower cost alternatives to full replacement. FEMA (2005) provides a detailed list of advantages and disadvantages of replacement and rehabilitation, which are summarized below.

Advantages of conduit replacement:

- Visual embankment/foundation evaluation after conduit removal.
- Allows repair of surrounding embankment that may have been damaged because of deteriorated condition of existing conduit.
- Allows for easy incorporation of filters designed according to the current state-of-practice.
- Potential for increasing the hydraulic capacity of the conduit.
- Conduit Replacement does not require specialty contractors, equipment or personnel.

Disadvantages of conduit replacement:

- Typically the highest cost alternative.
- Requires large open cut excavation through the embankment, which may put downstream areas at risk during construction.
- Potential for developing seepage paths at the contact between the unexcavated existing embankment and the replaced earthfill.

Advantages of conduit rehabilitation:

- Limited or no excavation required.
- Installation during weather conditions not suitable for replacement.
- It may be possible to maintain a full reservoir in some cases (i.e., conduit has upstream control and is accessible from downstream).
- Shortened construction schedule and reduced cost when compared to replacement.

Disadvantages to conduit rehabilitation:

- Not applicable for severely deteriorated conduits (i.e., conduits with severely compromised structural integrity, open joints or holes, pipe deformities, or conduits believed to have voids along the outside of the pipe). See Photo 1.
- Limitations for conduits with slight bends, deformities or non-uniform diameters.
- Most likely will require specialized contractors, and equipment for installation.
- May adversely affect seepage paths around the exterior of the existing conduit.

Additional advantages and disadvantages of the alternatives are also presented in “Technical Manual: Conduits through Embankment Dams,” produced by the Federal Emergency Management Agency (FEMA, 2005). The designer should consider both replacement and rehabilitation alternatives carefully and understand that each project site may have specific challenges that need to be considered.

Photo 1: Severely deteriorated CMP.[1]

Rehabilitation Alternatives

Of the two rehabilitation alternatives noted above, the more common option is sliplining (see Photo 2). High density polyethylene (HDPE) and properly coated steel pipe are the two most common pipes selected for sliplining rehabilitation and have similar design parameters. With little maintenance the service life of HDPE pipe can typically range between 50 and 100 years. Steel pipe requires provisions for adequate coating to provide similar levels of design life. Fiberglass reinforced pipe (FRP) and polyvinyl chloride (PVC) have also been used, but have drawbacks with regards to jointing (i.e., bell and spigot) and brittleness. Design considerations along with a comparison of HDPE pipe and coated steel pipe are summarized below.

Photo 2: Installing HDPE Liner pipe.[2]

Existing Conduit Inspections: It is important to complete a thorough cleaning and inspection of the existing conduit before moving forward with the design. For large diameter pipes the inspection can be completed visually by entering the pipe from either the downstream or upstream end, although confined space entry procedures should be followed. For small diameter pipes the inspection should be completed using a remote operated vehicle (ROV). The alignment (straightness) of the pipe, severity of deterioration, and location and dimensions of protrusions should be noted during the inspection.

Size Selection: When selecting the size and wall thickness of the carrier pipe, the designer needs to consider the hydraulic capacity, clearance from the existing pipe (annular space) including consideration of irregularities and protrusions, and the internal and external loadings. For large internal and external loadings, steel sliplining pipe may be required. The reduced diameter of the carrier pipe may not result in a reduced hydraulic capacity due to better hydraulic efficiency (lower friction losses) of the new carrier pipe. However, hydraulic capacity of the new carrier pipes needs to be checked against requirements.

Seepage Paths: After sliplining is complete the existing (host) pipe is essentially sealed. Depending on the severity of deterioration, the existing pipe may have been acting as a large drain for the embankment due to excessive seepage through the pipe/joints. Once the pipe is sealed, it is possible that phreatic levels in the embankment may increase, possibly increasing the potential for internal erosion (piping) along the conduit. To address this concern, the rehabilitation design should always consider adding a filter diaphragm near the downstream end of the pipe.

Thermal Expansion: In general, the sliplining pipe will be buried deep in the embankment and will experience limited temperature changes during the service life; however, the designer needs to understand the expansion and contraction limits of the selected pipe. Thermal expansion is not typically a large concern for steel pipe. However, if installed in very hot or very cold ambient air conditions, is it necessary to let the pipe reach equilibrium temperature before annular grouting.

[1] Photo courtesy of www.cleanculverts.com

[2] Photo courtesy of www.hydroworld.com

Joints: When possible, pipe sections should be fabricated in the shop. However, there are several alternatives available for field connecting sections of both HDPE and steel pipe as described in FEMA (2005). Joint testing should be completed prior to grouting.

Flotation: Both HDPE and steel pipes will want to float during grouting and must be restrained physically by external "centralizers" between the host and carrier pipes or by filling the pipes with water or sandbags.

Inlet and Outlet Structures: Rehabilitation or replacement of inlets and outlets is an important consideration in the design of alternatives for an outlet rehabilitation project. The ability to fabricate and install carrier pipes to fit a given inlet structure configuration often drives the decision whether to utilize or replace an inlet structure. Similarly, the desire for retrofitting seepage collars or the need to repair the existing downstream slope or provide energy dissipation are considerations for outlets.

Grouting: Grouting the annular space between the new pipe and the existing pipe is essential (see Photo 3). Only contractor's experienced in this type of grouting should be used for this specialized work. Typically grouting is completed from the downstream end with grout pumped to the upstream end through tremie pipes. Multiple tremie pipes of increasing lengths are used to inject grout and reduce the travel distance of the grout. Grouting should continue until the entire annular space has been filled and no voids remain. Vent/observation pipes are used to verify grout has filled the annular space. Securing bulkheads to contain the grout is also critical.

An in-situ alternative to sliplining is CIPP. This method is best suited for pipes that are not severely deteriorated, have limited to no protrusions, and have constant diameters. Many of the same design parameters should be considered. Curing of the carrier pipe is a critical step and one of two methods can be specified; pressurized steam, or pressurized hot water. Each has advantages and special consideration must be given to dry pipe installations versus where standing or flowing water will remain present within the host pipe during liner installation. Consultation with a CIPP manufacturer is highly recommended during the design process.

Photo 3: Grouting HDPE Liner pipe.[3]

Construction Considerations: Sliplining and CIPP pipe rehabilitation projects often involve working from one or both ends of the outlet with significant distance of pipe that cannot be accessed between. This introduces challenges during construction that must often be resolved in real time, i.e. once grouting or curing is started the effects cannot be reversed. For this reason adequate, experienced supervision is essential during critical activities such as liner installation and grouting. Additionally, experience has shown the value of "mini" preconstruction meetings involving all field personnel just prior to the start of those critical activities. A discussion "what if's" is a key component of those meetings to determine who makes necessary field decisions and what range of decisions might be needed to ensure project success.

Conclusion

This article provides a short summary of the design parameters and construction issues to consider during design of an existing conduit rehabilitation project. Before proceeding with a rehabilitation project, the design should answer the following questions.

Should I replace the existing conduit or rehabilitate it in place?

- Conduits that are severely deteriorated or possibly have voids adjacent to the conduit due to internal erosion should be replaced. A detailed cleaning and internal conduit inspection should be

[3] Photo courtesy of www.water.state.co.us

completed prior to selecting replacement or rehabilitation.

Which in-situ rehabilitation method should I select?

- A designer should evaluate both sliplining and CIPP for any rehabilitation project. The advantages and disadvantages of each alternative should be carefully evaluated for each specific site.
- An HDPE carrier pipe is a cost effective alternative for small-diameter conduits requiring a flexible pipe that is subjected to minor to nominal external and internal loadings. HDPE pipe may also be preferred in highly corrosive environments.
- A CIPP liner provides similar benefits to that of HDPE sliplining, but requires the use of a specialty contractor
- A steel carrier pipe may be the preferred choice for straight host pipes with larger diameters and nominal to high internal and external loadings.

Common Pitfalls in Sliplining:

- Suitable grout mix to grout full length of annulus
- Avoid pipe damage during construction. Inspect and repair any that occurs.
- Use experienced contractors
- Consider any potential reduction in capacity

FEMA's technical manuals provide detailed discussion of parameters that should be considered during the sliplining design process.

FEMA - Conduits through Embankment Dams

FEMA - Plastic Pipe Used in Embankment Dams

References

The following is a list of design references that should be used during design:

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- Rehabilitation of Large Diameter PCCP: Relining and Sliplining with Steel Pipe by Shah Rahman; Greg Smith; Richard Mielke; and Brent Keil
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